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National Eutrophication Survey, Corvallis, Oreg

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT

ON

SAM RAYBURN RESERVOIR

ANGELINA, JASPER, NACOGDOCHES,
SABINE, AND SAN AUGUSTINE COUNTIES

TEXAS

EPA REGION VI

WORKING PAPER NO. 657

WITH THE COOPERATION OF THE
TEXAS WATER QUALITY BOARD
AND THE
TEXAS NATIONAL GUARD
MARCH, 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning (§303(e)), water quality criteria/standards review (§303(c)), clean lakes (§314(a,b)), and water quality monitoring (§106 and §305(b)) activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loadings) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Texas Water Quality Board for professional involvement, to the Texas National Guard for conducting the tributary sampling phase of the Survey, and to those Texas wastewater treatment plant operators who voluntarily provided effluent samples.

Hugh C. Yantis, Jr., Executive Director of the Texas Water Quality Board, and John B. Latchford, Jr., Director, and the staff of the Field Operations Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Thomas Bishop, the Adjutant General of Texas, and Project Officer Colonel William L. Seals, who directed the volunteer efforts of the Texas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

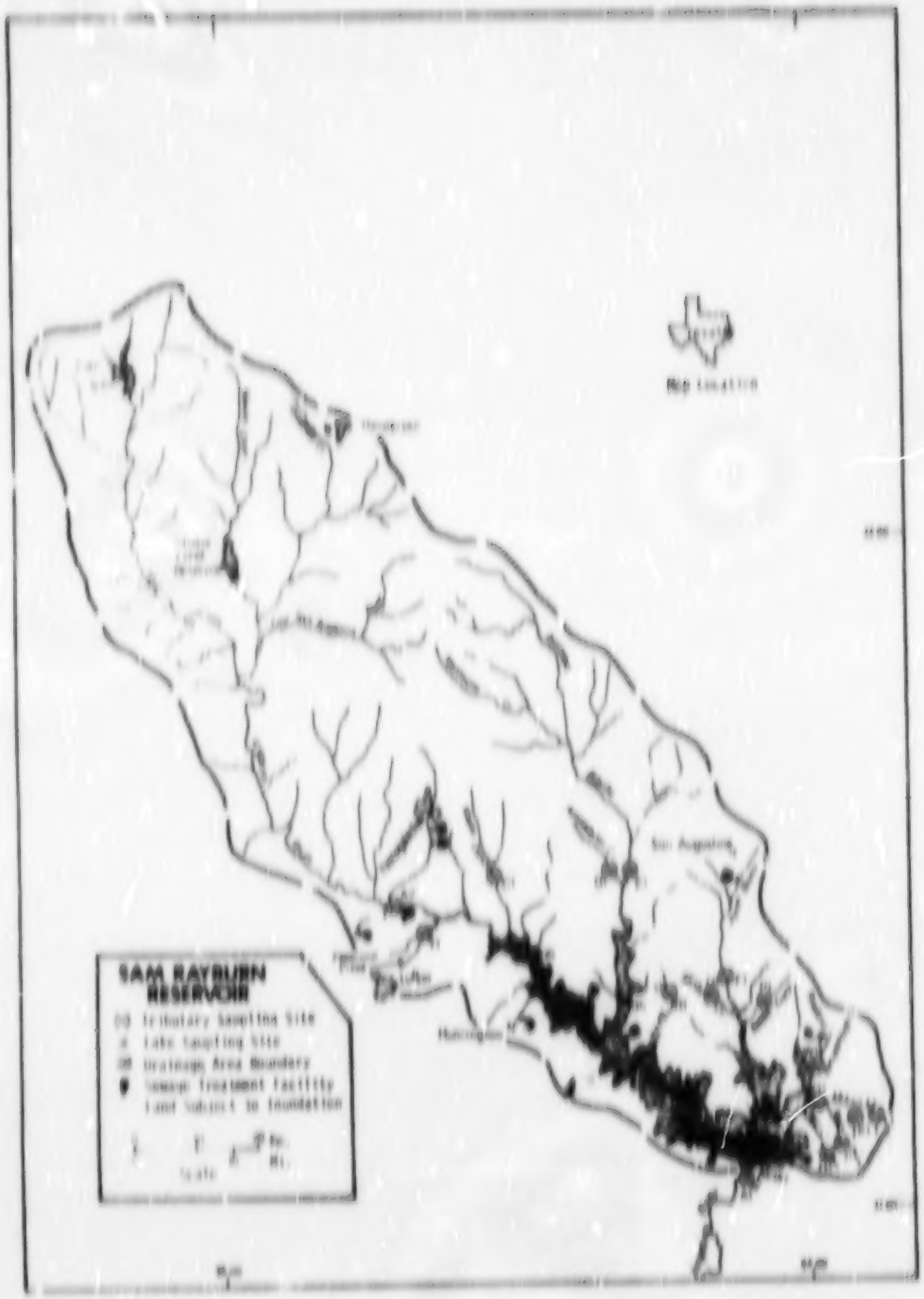
NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

State of Texas

NAME	COUNTY
Amistad	Val Verde
Bastrop	Bastrop
Belton	Bell, Coryell
Braunig	Bexar
Brownwood	Brown
Buchanan	Burnet, Llano
Caddo	Harrison, Marion, TX; Caddo Parish, LA
Calaveras	Bexar
Canyon	Comal
Colorado City	Mitchell
Corpus Christi	Jim Wells, Live Oak, San Patricio
Diversion	Archer, Baylor
Eagle Mountain	Tarrant, Wise
Fort Phantom Hill	Jones
Houston	Harris
Kemp	Baylor
Lake O'The Pines	Camp, Marion, Morris, Upshur
Lavon	Collin
Lewisville (Garza-Little Elm)	Denton
Livingston	Polk, San Jacinto, Trinity, Walker

Lyndon B. Johnson	Burnet, Llano
Medina	Bandera, Medina
Meredith	Hutchinson, Moore, Potter
O. C. Fisher (San Angelo)	Tom Green
Palestine	Anderson, Cherokee, Henderson, Smith
Possum Kingdom	Palo Pinto, Stephens, Young
Sam Rayburn	Angelina, Jasper Nacogdoches, Sabine, San Augustine
Somerville	Burleson, Lee, Washington
E. V. Spencer	Coke
Stamford	Haskell
Stillhouse Hollow	Bell
Tawakoni	Hunt, Rains, Van Zandt
Texoma	Cooke, Grayson TX; Bryan, Johnston, Love, Marshall, OK
Travis	Burnet, Travis
Trinidad	Henderson
Twin Buttes	Tom Green
White River	Crosby
Whitney	Bosque, Hill
Wright Patman (Texarkana)	Bowie, Cass


SAM RAYBURN RESERVOIR
Tributary Sampling Site
Lake Sampling Site
Drainage Area Boundary
Sewage Treatment Facility (not subject to inundation)

SAM RAYBURN RESERVOIR
STORET NO. 4827

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Sam Rayburn Reservoir is eutrophic; i.e., well supplied with nutrients and quite productive. Whether nutrient enrichment is beneficial or deleterious depends on the actual or potential effect on the uses of the reservoir. In this regard, the Texas Water Quality Board has indicated that there is little or no known impairment of the designated beneficial uses of this water body.

Sam Rayburn Reservoir ranked seventeenth in overall trophic quality when the 39 Texas reservoirs sampled in 1974 were compared using a combination of six parameters*. Fifteen of the reservoirs had less and one had the same median total phosphorus, 11 had less and six had the same median dissolved orthophosphorus, 22 had less and one had the same median inorganic nitrogen, nine had less mean chlorophyll a, and 12 had greater mean Secchi disc transparency. Marked depression or depletion of hypolimnetic dissolved oxygen occurred at most of the sampling stations in May and August and at station 6 in March.

Survey limnologists noted the presence of littoral macrophytes near sampling station 6 in March and near station 4 in November.

* See Appendix A.

B. Rate-Limiting Nutrient:

Because of nutrient changes in the samples, the algal assay results are not representative of conditions in the reservoir at the times the samples were taken.

The reservoir data indicate that the reservoir was phosphorus limited at most sampling stations in March and November, phosphorus limited at all stations in May, and nitrogen limited at all stations in August.

C. Nutrient Controllability:

1. Point sources--It is calculated that known point sources contributed about 20% of the total phosphorus load to the reservoir during the sampling year. The Nacogdoches wastewater treatment plants were the major contributors, collectively accounting for almost 17% of the total load.

During the sampling year, the reservoir received a total phosphorus loading less than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 16). It is calculated that 85% phosphorus removal at the Nacogdoches plants alone would reduce the loading to 0.26 $g/m^2/yr$. If Vollenweider's eutrophic level is applicable to Texas reservoirs, phosphorus control at the larger plants should ultimately shift conditions in the reservoir toward mesotrophy.

2. Non-point sources--It is estimated that non-point sources contributed about 80% of the total phosphorus load to the reservoir during the sampling year. The major contributors were the Angelina River (45%) and Attoyac Bayou (19%). The remaining tributaries and immediate drainage collectively accounted for about 16% of the total load.

II. RESERVOIR AND DRAINAGE BASIN CHARACTERISTICS[1]

A. Morphometry[11]:

1. Surface area: 463.48 kilometers^2.
2. Mean depth: 7.7 meters.
3. Maximum depth: >16.8 meters.
4. Volume: 3,574.902 x 10^6 m^3.
5. Mean hydraulic retention time: 1.4 years (based on 1972-1976 mean outflow).

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec.)*
Angelina River	4,410.8	23.100
Bayou Carrizo	211.3	0.500
Attoyac Bayou	1,302.8	9.070
Ayish Bayou	341.9	1.460
McKim Creek	74.6	0.202
Papermill Creek	78.5	0.103
Pomponaugh Creek	35.7	0.195
Minor tributaries & immediate drainage -	2,019.9	8.810
Totals	8,475.5	43.440

2. Outlet -

Angelina River	8,932.9**	42.380**

C. Precipitation***:

1. Year of sampling: 159.3 centimeters.
2. Mean annual: 109.2 centimeters.

1 Table of metric conversions--Appendix B.
11 At conservation pool level; Harrows, 1977.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of reservoir; lesser outflow due to evaporation.
*** See Working Paper No. 175.

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III. WATER QUALITY SUMMARY

Sam Rayburn Reservoir was sampled four times in 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at six stations on the reservoir (see map, page vi). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first and last visits, 18.9-liter depth-integrated samples were composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 16.8 meters at station 1, 11.9 meters at station 2, 16.2 meters at station 3, 15.8 meters at station 4, 5.5 meters at station 5, and 7.6 meters at station 6.

The sampling results are presented in full in Appendix D and are summarized in the following table.

[illegible]

[illegible]	1ST SAMPLING : [illegible]			2ND SAMPLING : [illegible]			3RD SAMPLING : [illegible]		
	[illegible]			[illegible]			[illegible]		
PARAMETER	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TEMP (C)	13.7 - 15.6	17.-	16.1	24.1 - 24.5	24.7	25.0	34.0 - 38.-	37.0	36.-
DISS OXY (MG/L)	1.0 - 9.2	7.2	6.0	8.0 - 9.-	4.0	4.0	0.0 - 8.0	4.0	4.2
CNDCTVY (MCMHO)	88.- - 167.-	138.-	113.-	138.- - 292.-	192.-	247.-	241.- - 546.-	356.-	251.-
PH (STAND UNITS)	6.6 - 7.5	7.1	7.1	6.8 - 8.0	7.5	7.6	6.7 - 8.2	7.3	7.2
TOT ALK (MG/L)	18.- - 34.-	23.-	23.-	24.- - 37.-	25.-	24.-	11.- - 65.-	31.-	27.-
TOT P (MG/L)	0.019 - 0.063	0.035	0.032	0.019 - 0.054	0.028	0.024	0.061 - 0.525	0.240	0.150
DFLT P (MG/L)	0.006 - 0.019	0.011	0.010	0.002 - 0.013	0.004	0.003	0.005 - 0.351	0.104	0.054
NO2+NO3 (MG/L)	0.240 - 0.228	0.151	0.190	0.038 - 0.298	0.111	0.076	0.020 - 0.040	0.021	0.029
AMMONIA (MG/L)	0.038 - 0.218	0.058	0.056	0.038 - 0.478	0.080	0.058	0.020 - 1.400	0.201	0.240
KJEL N (MG/L)	0.300 - 0.780	0.462	0.407	0.300 - 0.980	0.419	0.402	0.200 - 2.400	0.554	0.350
INORG N (MG/L)	0.600 - 0.340	0.294	0.256	0.060 - 0.538	0.194	0.158	0.540 - 1.400	0.322	0.605
TOTAL N (MG/L)	0.400 - 0.860	0.612	0.605	0.260 - 1.480	0.593	0.560	0.020 - 2.400	0.575	1.370
CHLPHYL A (UG/L)	5.0 - 7.7	6.3	5.0	2.5 - 17.3	6.8	6.6	2.0 - 9.7	4.6	1.0
SECCHI (METERS)	0.8 - 1.5	1.2	1.2	0.4 - 1.0	1.0	1.0	0.9 - 3.0	2.2	1.4

[illegible]

[illegible]

[illegible]

PARAMETER	RANGE	MEAN	MEDIAN
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/18/74	1. Melosira sp.	2,395
	2. Chroomonas sp.	620
	3. Cryptomonas sp.	169
	4. Nitzschia sp.	145
	5. Centric diatoms	145
	Other genera	340
	Total	3,823
05/24/74	1. Chroomonas sp.	627
	2. Melosira sp.	207
	3. Cryptomonas sp.	165
	4. Stephanodiscus sp.	165
	5. Synedra sp.	132
	Other genera	669
	Total	2,045
08/23/74	1. Dactylococcopsis sp.	7,930
	2. Lyngbya sp.	1,478
	3. Anabaenopsis sp.	1,034
	4. Melosira sp.	198
	5. Synedra sp.	197
	Other genera	394
	Total	11,231
11/08/74	1. Chroomonas sp.	1,204
	2. Melosira sp.	339
	3. Cryptomonas sp.	113
	4. Dactylococcopsis sp.	113
	5. Scenedesmus sp.	113
	Other genera	149
	Total	2,031

B. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
03/18/74	1	5.6
	2	6.5
	3	6.9
	4	7.1
	5	7.7
	6	5.8
06/24/74	1	8.5
	2	9.1
	3	12.0
	4	12.3
	5	13.1
	6	4.8
08/23/74	1	8.8
	2	4.5
	3	3.1
	4	6.0
	5	8.7
	6	2.9
11/08/74	1	1.9
	2	4.4
	3	2.2
	4	7.4
	5	13.4
	6	2.9

C. Limiting Nutrient Study:

Because of significant changes in nutrients in the samples during shipment from the field to the laboratory, the algal assay results are not representative of conditions in the reservoir at the times the samples were collected.

The reservoir data indicate a temporal and spatial combination of limiting nutrients, although it will be noted that the stations nearest major point sources (station 6) and a major tributary (station 5) tended toward nitrogen limitation, while the stations further away tended toward phosphorus limitation.

Following is a tabulation of the mean inorganic nitrogen/orthophosphorus ratios for each of the sampling stations and times with the indicated limiting nutrient in parentheses.

Station	03/18/74	05/24/74	08/23/74	11/08/74
1	27/1 (P)	53/1 (P)	1/1 (N)	27/1 (P)
2	20/1 (P)	85/1 (P)	1/1 (N)	21/1 (P)
3	22/1 (P)	88/1 (P)	4/1 (N)	34/1 (P)
4	18/1 (P)	30/1 (P)	3/1 (N)	27/1 (P)
5	16/1 (P)	22/1 (P)	2/1 (N)	9/1 (N)
6	9/1 (N)	18/1 (P)	5/1 (N)	5/1 (N)

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IV. NUTRIENT LOADINGS
(See Appendix I for data)

For the determination of nutrient loadings, the Texas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the months of April and May when two samples were collected. Sampling was begun in September, 1974, and was completed in August 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Texas District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source louds, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in kg/km²/year, at stations C-1, F-1, G-1, and I-1, and multiplying the means by the ZZ area in km².

The operators of the Lufkin State School, Pineland, Lake Sam Rayburn KOA, Westwood, and Rayburn Country Development Corp. wastewater treatment plants provided monthly effluent samples and corresponding flow data. The operators of the San Augustine, Twin Dikes Marina, Shirley Creek Corp., Jackson Hill Marina, Huntington, Nacogdoches #1, and

* See Working Paper No. 175.

Nacogdoches #2A plants did not participate; nutrient loads from these sources were estimated at 1.134 kg P and 3.401 kg N/capita/year, and flows were estimated at 0.3784 m^3/capita/day.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
San Augustine	2,200	stab. pond	832.7	Ayish Bayou
Lake Sam Rayburn KOA	25	act. sludge	8.5	Sam Rayburn Reservoir
Twin Dikes Marina	40	act sludge	15.1	Sam Rayburn Reservoir
Rayburn Country Development Corp.	300	act. sludge	204.4	Sam Rayburn Reservoir
Shirley Creek Corp.	40	act. sludge	15.1	Sam Rayburn Reservoir
Jackson Hill Marina	40	act. sludge	15.1	Sam Rayburn Reservoir
Lufkin State School	1,500	act. sludge	569.7	Procella Creek/ Angelina River
Pineland	1,200	tr. filter	746.3	Pomponaugh Creek
Westwood	234	act. sludge	34.1	Sam Rayburn Reservoir
Huntington**	600	Imhoff tank	227.1	Gilliland Creek
Nacogdoches #2A	18,000	act. sludge	6,811.0	Bayou LaNana
Nacogdoches #1	2,500	tr. filter	946.2	Bayou LaNana

2. Known industrial - None

* Treatment plant questionnaires; Wyatt, 1976.
** Anonymous, 1971.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Angelina River	62,230	44.6
Bayou Carrizo	1,065	0.8
Attoyac Bayou	26,410	18.9
Ayish Bayou	785	0.6
McKim Creek	200	0.2
Papermill Creek	850	0.6
Pomponaugh Creek	1,350	1.0
b. Minor tributaries & immediate drainage (non-point load) -	10,100	7.2
c. Known municipal STP's -		
San Augustine	2,495	1.8
Lake Sam Rayburn KOA	15	<0.1
Twin Dikes Marina	45	<0.1
Rayburn Country Development Corp.	195	0.1
Shirley Creek Corp.	45	<0.1
Jackson Hill Marina	45	<0.1
Lufkin State School	685	0.5
Pineland	1,035	0.7
Westwood	40	<0.1
Huntington	680	0.5
Nacogdoches #2A	20,410	14.6
Nacogdoches #1	2,835	2.0
d. Septic tanks* -	35	<0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	8,005	5.7
Total	140,055	100.0

2. Outputs -

Lake outlet - Angelina River 80,910

3. Net annual P accumulation - 59,145 kg.

* Estimate based on 69 shoreline dwellings and 16 parks; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Angelina River	655,950	38.8
Bayou Carriza	13,670	0.8
Attoyac Bayou	251,975	14.9
Ayish Bayou	24,535	1.5
McKim Creek	3,570	0.2
Papermill Creek	7,800	0.4
Pompona'gh Creek	11,745	0.7
b. Minor trilytaries & immediate drainage (non-point load) -	143,415	8.5
c. Known municipal STP's -		
San Augustine	7,480	0.4
Lake Sam Rayburn KOA	35	<0.1
Twin Dikes Marina	135	<0.1
Rayburn Country Development Corp.	405	<0.1
Shirley Creek Corp.	135	<0.1
Jackson Hill Marina	135	<0.1
Lufkin State School	1,325	0.1
Pineland	2,725	0.2
Westwood	160	<0.1
Huntington	2,040	0.1
Nacogdoches #2A	61,220	3.6
Nacogdoches #1	8,500	0.5
d. Septic tanks* -	1,300	0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	493,765	29.2
Total	1,692,020	100.0

2. Outputs -

Lake outlet - Angelina River 1,554,360

3. Net annual N accumulation - 137,660 kg.

* Estimate based on 69 shoreline dwellings and 16 parks; see Working Paper No. 175.
** See Working Paper No. 175.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Angelina River	14	149
Bayou Carriso	5	64
Attoyac Bayou	20	191
Ayish Bayou	2	72
McKim Creek	3	48
Papermill Creek	11	99
Pumpenaugh Creek	38	330

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributaries	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
Analaderos Creek	0.054	0.630
Mill Creek	0.019	0.548
Rock Creek	0.015	0.545
West Prong McKim Creek	0.017	0.592
East Prong McKim Creek	0.013	0.584
Bobbit Creek	0.059	0.745
Sandy Creek	0.065	0.756
Harvey Creek	0.073	0.705

f. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.30	0.13	3.7	0.3

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Sam Rayburn Reservoir:

"Dangerous" (eutrophic loading)	0.46
"Permissible" (oligotrophic loading)	0.23

V. LITERATURE REVIEWED

Anonymous, 1971. Inventory of municipal waste facilities. EPA Pub. No. GWP-1, vol. 6, Wash., DC.

Barrows, David, 1977. Personal communication (reservoir morphometry and hydraulic retention time). Canyon Proj. Off., Fort Worth Distr., Corps of Engrs., New Braunfels, TX.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

Wyatt, Linda B., 1976. Personal communication (point sources impacting reservoir). TX Water Qual. Bd., Austin.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE CODE	LAKE NAME	[illegible] TOTAL *	[illegible] [illegible] *	[illegible] [illegible] SEC	[illegible] CALORIE	[illegible] [illegible]	[illegible] [illegible] [illegible] *
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	LAKE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	LAKE [illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	LAKE OF THE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] & [illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	LAKE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] Data to be used in Appendix

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

LAKE CODE	LAKE NAME	[illegible] TOTAL *	[illegible] [illegible] *	[illegible] [illegible] SEC	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible] [illegible] *	[illegible] [illegible]
[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

PERCENT OF LAKES WITH HIGHER VALUES NUMBER OF LAKES WITH HIGHER VALUES

LAKE CODE	LAKE NAME	[illegible] TOTAL P	[illegible] INORG N	[illegible] ALK	[illegible] DY PH	[illegible] CA	[illegible] DISS ORTHO P	[illegible] SD
429	[illegible] LAKE	24 (113)	55 (259)	24 (114)	3 (14)	67 (316)	38 (179)	224
430	[illegible] LAKE	14 (70)	67 (339)	5 (25)	16 (79)	62 (313)	34 (166)	254
431	[illegible] LAKE	58 (339)	37 (340)	67 (334)	42 (354)	17 (84)	54 (269)	372
432	[illegible] LAKE	32 (159)	78 (384)	37 (184)	21 (89)	82 (344)	38 (159)	253
433	[illegible] LAKE	11 (44)	91 (364)	13 (51)	34 (99)	72 (279)	13 (51)	178
434	[illegible] LAKE	36 (144)	34 (139)	61 (239)	45 (177)	17 (69)	21 (79)	217
435	[illegible] LAKE	68 (339)	23 (79)	42 (264)	62 (314)	17 (81)	84 (323)	404
436	[illegible]	2 (9)	96 (389)	11 (49)	5 (29)	97 (389)	0 (0)	249
437	[illegible]	59 (229)	21 (79)	58 (229)	61 (239)	49 (179)	63 (249)	393
438	[illegible]	84 (339)	96 (389)	76 (299)	69 (344)	17 (84)	63 (249)	348
439	[illegible] LAKE	63 (249)	51 (199)	76 (389)	71 (279)	17 (69)	76 (299)	257

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]
29	[redacted]	[redacted]	234
30	[redacted]	[redacted]	227
31	[redacted]	[redacted]	204
32	[redacted]	[redacted]	203
33	[redacted]	[redacted]	176
34	[redacted]	[redacted]	173
35	[redacted]	[redacted]	144
36	[redacted]	[redacted]	139
37	[redacted]	[redacted]	135
38	[redacted]	[redacted]	130
39	[redacted]	[redacted]	91

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

[illegible]

[illegible]

APPENDIX D

PHYSICAL and CHEMICAL DATA

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[illegible]
[illegible]
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[illegible]	11	78	[illegible]	[illegible]	
	11	78	[illegible]	[illegible]	
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	11	78	[illegible]	[illegible]	
	11	78	[illegible]	[illegible]	
[illegible]	14	78	[illegible]	[illegible]	
	14	78	[illegible]	[illegible]	
	14	78	[illegible]	[illegible]	
	14	78	[illegible]	[illegible]	
	14	78	[illegible]	[illegible]	
	14	78	[illegible]	[illegible]	
[illegible]	12	85	[illegible]	[illegible]	
	12	85	[illegible]	[illegible]	
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	12	85	[illegible]	[illegible]	
[illegible]	14	88	[illegible]	[illegible]	
	14	88	[illegible]	[illegible]	
	14	88	[illegible]	[illegible]	
	14	88	[illegible]	[illegible]	
	14	88	[illegible]	[illegible]	

APPENDIX E

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TO	DAY	FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TO	[illegible]	FEET	[illegible]	[illegible]	[illegible]	[illegible] *	[illegible] *
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7x45x937	03	45	0.837	0.456	5.558	0.865	0.432
7x73b485	69	45	0.836	0.465	0.834	0.8859	0.4389
7x11u82	89	38	0.837	0.468	0.385	0.823	0.438
7x12f87	46	48	0.834	0.468	0.832	0.839	0.442
75x1v11	04	88	0.834	0.765	0.832	0.8774	0.426
75x927m	04	13	0.834	0.388	0.824	0.8549	0.4389
75x3v81	68	45	0.838	0.238	0.828	0.885	0.4387
75x9w05	04	38	0.835	0.538	0.827	0.8854	0.4387
75x4w28	48	88	0.835	0.236	0.835	0.833	0.432
75x5k83	04	45	0.835	0.458	0.388	0.885	0.438
75x95n4	48	58	0.835	0.388	0.846	0.885	0.4389
75x8w87	38	75	0.835	0.758	0.835	0.865	0.4387
75x7r14	04	15	0.838	0.758	0.879	0.833	0.434
75x6w2n	48	78	0.834	0.468	0.828	0.8854	0.428

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]
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74/09/23	04	00							
0400-			0.496	3.148	0.4274	1.488	1.426	0.192	0.145
74/09/23	15	00							
74/10/29	04	30							
0400-			0.240	5.868	0.790	1.478	2.386	0.157	0.155
74/10/29	15	30							
74/11/26	04	00							
0400-			0.488	3.386	0.4569	0.868	1.488	0.179	0.155
74/11/26	15	00							
74/12/30	00	00							
0400-			0.246	5.688	0.4584	1.258	1.488	0.154	0.159
74/12/30	06	15							
75/01/31	04	30							
0400-			0.268	4.488	0.4564	0.968	1.488	0.159	0.159
75/01/31	15	00							
75/02/28	04	00							
0400-			0.246	4.488	0.4138		3.488	0.178	0.159
75/02/28	15	00							
75/03/31	00	30							
0400-			0.488	3.458	0.4362	0.248	2.588	0.134	0.153
75/03/31	15	00							
75/04/30	04	30							
0400-			0.458	3.458	0.4346	0.448	0.488	0.143	0.158
75/04/30	15	00							
75/05/30	04	00							
0400-			0.454	0.488	0.4358	2.488	0.788	0.178	0.158
75/05/30	15	00							
75/06/30	00	00							
0400-			0.475	11.588	0.4371	0.488	11.388	0.179	0.153
75/06/30	16	30							
75/07/29	04	00							
0400-			0.352	38.836	0.4329	0.458	0.458	0.141	0.132
75/07/29	15	00							
75/08/29	04	00							
0400-			0.427	16.458	0.4325	2.438	0.488	0.143	0.138
75/08/29	13	30							

* VALUE MISSING OR
LESS THAN INDICATED.

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